

## INERTIAL CORRECTIONS BY DYNAMIC ESTIMATION

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This paper presents the highlights of an Engineering Memorandum, "Dynamic Estimation for Floated Gradiometers," JPL EM 314-441, 6-5-88, by D. Sonnabend and W. M. McEneaney. The original impetus for the work was that gradiometers, in principle, measure components of the gravity gradient tensor, plus rotation effects, similar to centrifugal and Coriolis effects in accelerometers. The problem is that the rotation effects are often quite large, compared to the gradient, and that available inertial instruments can't measure them to adequate accuracy. The paper advances the idea that, if the instruments can be floated in a package subject to very low disturbances, a dynamic estimation, based on the Euler and translational equations of motion, plus models of all the instruments, can be used to greatly strengthen the estimates of the gradient and the rotation parameters. Moreover, symmetry constraints can be imposed directly in the filter, further strengthening the solution.

There are direct applications of these ideas to relativistic gravity experiments. First, the gradient tensor is really a subset of the Riemann tensor; so one can, in principle, make a direct measurement of curvature. Once the measurement model has been updated to a fully relativistic treatment of the rotation effects, the present estimation structure can be used to determine how well local curvature, and the PPN parameters, can be extracted, given the properties of the instrument ensemble. Gravitomagnetic effects may even be accessible, as suggested by Mashoon.

Another possibility, long advanced by Paik, would be the detection of "fifth force" terms in the geopotential. His idea is that, while the gradient tensor is traceless for any Newtonian potential, the addition of a consistent-type potential would lead to a non-zero trace, which should be readily measurable, in spite of large uncertainties in the earth's mass distribution. A problem here is that the centrifugal-like terms are not traceless; so again, dynamic estimation may help separate them from fifth force effects, if they exist.

The existing filter structure was devised to examine the measurement of the (Newtonian) geopotential, and does not stretch to cover either of these kinds of investigations. However, once a fully relativistic treatment of the gradient tensor, and of the rotation corrections, is available to us, it should not be hard to augment the filter state to include the uncertain parameters we are after; *i.e.*, some of the PPN parameters and the coefficients of one or more Yukawa potentials.

At present, the filter is built around a 14-element state vector, including the disturbance force on the instrument package, the instrument angular velocity and attitude, and 5 independent elements of the gradient tensor (assumed both symmetric and traceless). Possible measurements include linear and angular accelerometers, gyros, a star tracker, and a full tensor gradiometer. Any components of any of these measurements may be deleted. The effects of process noise are incorporated by means of Gauss-Markov processes for both air drag and gradient arising from variable geology. The latter is a very simple (but analytically tractable) scheme involving random mountains on a locally flat earth. While suitable for appraising the value of dynamic estimation in this scenario, several parts of the filter will need

to be upgraded to deal with a specific mission design. This is especially true if relativistic effects are to be included.

Finally, even for purely geophysical studies, it will be necessary to add a module that includes the errors in transforming from the instrument location and attitude to fixed earth (or other more or less inertial) coordinates. This will require the inclusion of satellite tracking in the measurement ensemble, a fairly extensive revision, particularly if a relativistic treatment is required. All of this could be done in a few months if support is available.